Seasonal Influences on Blood Pressure in High Normal to Mild Hypertensive Range

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To investigate the seasonal influences on various arterial blood pressure measurements, 22 subjects in the high normal to mild hypertensive range were examined twice following the same protocol. In one group (13 subjects), measurements were first done in warm conditions and repeated 5–7 months later in cold conditions; in the second group (nine subjects) a reverse sequence was followed. Blood pressure was measured under casual conditions during a hand grip exercise test, mental arithmetic test, and submaximal multistage bicycle exercise test; during the following 24 hours, blood pressure was measured serially with a noninvasive ambulatory blood pressure recorder. Daily outdoor maximum and indoor laboratory temperatures were also obtained. In the cold season, significantly higher values (on the average by 5–10 mm Hg, \( p < 0.01 \)) were obtained in both groups for mean diastolic daytime blood pressure. For other measurements, a trend toward higher values in the cold season was observed in both groups, although statistical significance was not obtained in all instances. For nighttime measurements, irrespective of the seasonal sequence, lower values were observed in the second session. Significant correlations were found between the differences in the average daytime ambulatory blood pressures and the corresponding changes of daily maximum outdoor temperatures after 5–7 months. These observations indicate that arterial blood pressure may be strongly influenced by environmental temperature. This phenomenon should be taken into account both in the evaluation of the individual hypertensive patients and in the design and analysis of studies on arterial hypertension, especially when ambulatory blood pressure techniques are employed. (Hypertension 1989; 14:22–27)

That hypertensive patients often need less pharmacological treatment in summer than in winter is a common experience in clinical practice. In fact, a definite seasonal influence on arterial blood pressure (with values during the winter higher by 2–10 mm Hg than in the summer) has been demonstrated by various studies based on single or repeated measurements that were obtained by a standard sphygmomanometer and by a recent study in children whose blood pressure measurements were taken with an automatic recorder.\(^1\)\(^-\)\(^5\)

Several noninvasive devices for 24-hour serial ambulatory blood pressure recording have recently been developed and are increasingly employed in clinical practice. Although their value in the clinical management of hypertension remains to be established, increasing evidence has been obtained for the superiority of these devices compared with isolated manual readings for correlation with target organ damage, the clinical and prognostic assessment of patients, and the evaluation of antihypertensive treatment.\(^6\)\(^-\)\(^12\)

The blood pressure responses to cardiovascular reactivity tests have also often been employed in the diagnostic approach to the hypertensive patient.\(^13\)\(^-\)\(^18\)

Despite the growing interest in ambulatory blood pressure monitoring and the long-lasting application of stress tests in arterial hypertension, to our knowledge, the possible effects of seasonal changes on blood pressure determinations obtained by these techniques have not as yet been studied. The aim of this study is to report on the influences of seasonal variations observed in a group of subjects in the high normal to mild hypertensive range by comparing measurements after an interval of 6 months (i.e., once in a "cold" and once in a "warm" period).

Subjects and Methods

The investigation involved 22 subjects (14 men and eight women). Two subjects were students (one
man and one woman), four (all men) were blue-collar workers with light physical activity, 12 (nine men and three women) were white-collar workers, and four were housewives. All subjects had been referred to our outpatient clinic because of a mild to moderate blood pressure elevation detected by their family practitioner. At the time of their first visit at our clinic, the ambulatory systolic and diastolic blood pressure (mean of three casual measurements in the sitting position) of the patients ranged between 120 and 150 and 80 and 100 mm Hg, respectively, and the average age was 38 years (range 17–54, SD±9.7 years). None had clinical or chest x-ray indications of aortic coarctation or abdominal vascular bruits. Routine hematochemical values including serum electrolytes, plasma creatinine, and urinalysis were normal for all subjects. No evidence of major organ damage was present on clinical grounds or on the basis of fundus oculi, chest x-ray, and electrocardiogram (ECG). All subjects ceased any medical treatment (including contraceptive pills) before and for the entire duration of the study.

All patients were evaluated twice at an interval of 5–7 months following the same protocol: once in a warm (April–September) and once in a cold (November–March) period. The sequence of the two sessions was determined by random assignment of an original group of 25 subjects: 13 to the warm/cold group and 12 to the inverse sequence. The final results, however, refer to 22 subjects because of dropouts in the latter group. Thirteen subjects (group A) were first measured in warm conditions and nine (group B) in cold conditions. The data were available for casual blood pressure in all subjects, for stress tests in 20 subjects (13 from group A and seven from group B), and for ambulatory blood pressure monitoring in 20 subjects (12 from group A and eight from group B). For one patient of group A, nighttime ambulatory blood pressure measurements were not available for technical reasons.

The subjects arrived at the outpatient clinic, after a light meal at home, at 2:30 PM and spent between 20 and 30 minutes in a waiting room before starting blood pressure measurements. The rooms where the measurements were done were heated in the winter but not air-cooled in the summer. The subjects, wearing light clothes, were weighed in both sessions, and indoor temperature was recorded. Casual blood pressure was first measured in a quiet room by determination of the average of three consecutive blood pressure values after the subject had been sitting for 5 minutes. All patients then performed a handgrip test (30% of maximal voluntary contraction of one hand for 3 minutes in supine position), a mental arithmetic test (arithmetic subtractions performed aloud for 5 minutes in supine position), and a submaximal multistage exercise (in upright position on a bicycle ergometer, with increments of 25 W every 2 minutes until 85% of the maximum heart rate for age or exhaustion (dyspnea or fatigue). During the test, a complete ECG was continuously monitored and blood pressure was measured every minute. All tests were done in the same sequence at intervals of 30 minutes. All blood pressure measurements were obtained with an automatic noninvasive, oscillometric device (Dinamap 845-Xt, Vital Signs Monitor, Criticon Inc., Tampa, Florida) with the exception of the bicycle exercise, for which a standard sphygmomanometer (always by the same observer) was used. The responses of blood pressure and heart rate to the various tests were assessed as the absolute difference between basal (average of the last three measurements before the test) and peak values, except for bicycle exercise for which the slopes of the regression lines of systolic blood pressure and heart rate on time were computed.

At the end of the test session (around 5:30 PM) all patients began a 24-hour blood pressure and heart rate monitoring period with a noninvasive portable recorder (ICR 5200 Ambulatory Blood Pressure System, Spacelabs, Inc., Hillsboro, Oregon). Readings were obtained at 15-minute intervals until midnight, at 30-minute intervals from midnight to 6:00 AM, and again at 15-minute intervals until the end of the recording (around 2:00 PM). At the time of their first visit, all subjects were told to attend their usual activities but to avoid vigorous exercise during the whole blood pressure recording time, and on their second visit, they were asked to follow the same pattern of activity as during their first monitoring. On both occasions, all subjects were asked to keep a diary of their activities. None returned to work in the afternoon after the test session; eight subjects (five from group A and three from group B) went to work the following morning (during both recording days). All these subjects worked in an indoor environment, which was heated during winter. Two subjects (one of group A and one of group B) worked in an air-conditioned office during the summer. All subjects lived in apartments that were heated during the winter but not air-cooled during the summer.

Clearly spurious values and measurements for which pulse blood pressure was lower than 15 mm Hg were deleted.

The means of the systolic and diastolic blood pressure and heart rate were calculated for the time the patient was awake and asleep (defined as average daytime and nighttime blood pressure, respectively). The standard deviations and variation coefficients were also calculated as indexes of blood pressure variability.

The maximum outdoor temperature for the blood pressure recording days was obtained from the 46th Airbrigate’s Meteorologic Office of the Italian Airforce of Pisa.

Statistical evaluation was made by paired t test and regression analysis with a STATVIEW package (Abacus Concepts Inc., Calabases, California) implemented on an Apple Macintosh SE personal computer.
TABLE 1. Evaluation of Characteristics of Two Subgroups Studied

<table>
<thead>
<tr>
<th>Variable</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>13</td>
<td>9</td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>8/5</td>
<td>6/3</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>36±11</td>
<td>41±7 (NS)</td>
</tr>
<tr>
<td>Body surface area (m²)</td>
<td>1.8±0.1</td>
<td>1.9±0.2 (NS)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>68±9.1</td>
<td>72±13.4 (NS)</td>
</tr>
</tbody>
</table>

Values are expressed as mean±SD. Group A is subgroup that was first measured in warm conditions and Group B is subgroup that was first evaluated in cold conditions. NS, no statistical significant difference between the two groups (unpaired t test).

Results

The average values of the maximum outdoor temperatures in the warm and cold periods were 24.9±6.4° C and 12.04±4.4° C, respectively (mean±SD, p<0.001). Less marked, though significant differences were observed for indoor temperatures (24.2±3.8° C and 20.2±1.4° C, p<0.001). No significant difference was observed for body weight in the two seasons.

The two subgroups studied (i.e., those who were measured first in warm conditions [group A] and those who were measured first in cold conditions [group B]) were matched for sex distribution, age, and body build (Table 1).

The means of casual blood pressure and daytime and nighttime ambulatory blood pressures obtained in the two sessions in the two subgroups are reported in Table 2. As shown in this table, casual blood pressure remained on average unchanged in group A and decreased in group B. This decrement was significant (p<0.01) for diastolic blood pressure but fell short of statistical significance for systolic measurements. Mean daytime measurements of diastolic blood pressure increased significantly (on average by 5 mm Hg) in group A, and both systolic and diastolic pressure decreased significantly (on average by 12 and 10 mm Hg, respectively) in group B. Finally, a significant decrease of systolic blood pressure was observed for mean nighttime measurements in both groups. No significant seasonal effects were observed for heart rate or for the indexes of blood pressure variability.

The seasonal effect on repetition of blood pressure measurements is further visualized in Figure 1, which reports the individual differences between the second and first measurements for the two subgroups. As shown in this figure, a markedly different pattern of distribution was present for the changes of average daytime blood pressure, especially diastolic measurements (i.e., patients who were first seen in the summer had increased blood pressures on their second evaluation, and those who were studied first in the winter had the opposite response). A less evident but similar trend was also present for casual blood pressure. Finally, average nighttime systolic and, to a lesser extent, diastolic blood pressure had a tendency toward lower values during the second recording, irrespective of the seasonal sequence.

Table 3 reports the results obtained for the cardiovascular stress test. This table essentially confirms the results reported for casual and ambulatory blood pressure measurements reported in Table 2. In fact, a trend toward higher values in the cold season was observed for baseline and peak values for the handgrip and mental test in both groups, albeit a statistical significance was not obtained in all instances. For the bicycle test, no differences were found for the response of blood pressure; for heart rate, an increased reactivity was observed during the cold period, which was significant in group B and approached statistical significance in group A.

As shown in Figure 2, inverse, highly significant correlations were found for the pooled data between the individual differences of the average daytime blood pressures and the corresponding changes of maximum outdoor temperatures. No other signific-
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FIGURE 1. Graphs comparing individual changes of casual blood pressure and mean daytime and nighttime blood pressure (BP) after an interval of 5-7 months in subgroup that was first examined in warm conditions and had repeat measurements in cold conditions (group A, open symbols) and in subgroup that underwent reverse sequence (group B, full symbols). Left part of each panel refers to changes observed for diastolic blood pressure and right part to changes for systolic blood pressure. Mean±1 SEM for each subgroup is also reported.

casual blood pressure

mean day-time BP

mean night-time BP

cant correlations were observed for casual, nighttime average blood pressure and blood pressure responses to the stress tests either with laboratory indoor or maximum outdoor temperature changes. Finally, no correlation was found between the individual differences of blood pressure and body build.

Discussion

The aim of the present study was to assess the effect of seasonal influences on arterial blood pressure measurements obtained under various conditions by comparison of readings obtained in the same subjects at 5-7-month intervals, once in warm and once in cold conditions. We attempted to exclude an effect because of familiarization with repeated measurements by random assignment of the order of the different measurements. However, because of uneven dropout rates in the two subgroups, the data could not easily be pooled together. Despite this limitation, we believe that our data strongly suggest an important influence on blood pressure of environmental temperature superimposed on a less evident familiarization effect.

A seasonal influence on arterial blood pressure has previously been described by Rose in 1961; similar findings were reported by Brennan et al, who analyzed a large number of data collected for a pharmacological treatment trial for mild hypertension, by Hata et al, who compared a smaller group of patients with borderline and established essential hypertension, and by Jenner et al in a recent study on 9-year-old children. The seasonal influence on arterial blood pressure has a clinical relevance known to many hypertensive patients, who spontaneously decrease their antihypertensive medications during the summer, and to many doctors, who observe that patients in the borderline to mild hypertensive range often need pharmacological treatment only in winter. An increased sympathetic nervous activity (as indicated by urinary and plasma catecholamine levels) and increased sodium intake (as indicated by urinary sodium excretion) have been implicated as potential mechanisms whereby blood pressure increases in cold conditions. Finally, as suggested by Brennan, the seasonal effects on arterial blood pressure may, at least in part, account for the reported higher winter mortality from ischemic heart disease and stroke.

Our results confirm and extend these observations and suggest that clear seasonal influences can be detected in small scale studies, especially when integrated evaluations by ambulatory monitoring are used, and that these seasonal effects are limited to daytime.

Several factors may account for the closer relation with seasonal influences observed for the average daytime blood pressure; it may merely be a consequence of the higher accuracy, compared with single readings, provided by ambulatory monitoring in the estimation of the individual's blood pressure level. On the other hand, this relation could also reflect a more direct influence on environmental temperature on blood pressure values, which were obtained, at least in part, while the patients were in an outdoor environment. The importance of environmental temperature is also supported by the strong correlation observed between daytime ambulatory blood pressure changes and temperature variations in the two sessions. However, it seems plausible that the effects of outdoor temperature are not limited to outdoor measurements. In our study, average daytime blood pressures reflect, to a substantial amount, measurements obtained in an indoor environment, and furthermore, a seasonal effect was also observed for indoor measurements, such as casual blood pressure and blood pressure values during the stress tests.
### Table 3. Comparison of Responses to Cardiovascular Reactivity Tests in Two Subgroups Studied

<table>
<thead>
<tr>
<th>Variables</th>
<th>Group A (n, 13)</th>
<th>Group B (n, 7)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Session 1</td>
<td>Session 2</td>
</tr>
<tr>
<td>Hand-grip</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline (mm Hg)</td>
<td>124/75 (±10/8)</td>
<td>130<em>79</em> (±6/7)</td>
</tr>
<tr>
<td>Peak (mm Hg)</td>
<td>140/81 (±13/7)</td>
<td>141/88* (±10/8)</td>
</tr>
<tr>
<td>Mental test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline (mm Hg)</td>
<td>123/74 (±9/7)</td>
<td>126/77* (±7/7)</td>
</tr>
<tr>
<td>Peak (mm Hg)</td>
<td>145/85 (±11/7)</td>
<td>144/87 (±9/10)</td>
</tr>
<tr>
<td>Bicycle test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baseline (mm Hg)</td>
<td>127/88 (±13/9)</td>
<td>130/92 (±12/9)</td>
</tr>
<tr>
<td>Slope SBP (mm Hg/min)</td>
<td>9.0±2.6</td>
<td>8.4±3.4</td>
</tr>
<tr>
<td>Slope HR (beats/min/min)</td>
<td>9.9±2.5</td>
<td>10.9±2.1</td>
</tr>
</tbody>
</table>

Values are expressed as mean±SD. Comparison is made by paired t test. SBP, systolic blood pressure; HR, heart rate.

*p<0.05.
**p<0.01.
***p<0.001.

In contrast to average daytime blood pressures, no seasonal differences were observed for nighttime measurements. This finding may simply reflect smaller differences in temperatures experienced by the sleeping subjects. In addition, since it is well known that sleep is associated with a pronounced reduction of the sympathetic tone, the lack of seasonal effects on nighttime blood pressure might in some way reflect a role of the adrenergic system in mediating the seasonal changes of arterial blood pressure. Also, nighttime measurements showed a significant tendency toward a decrease on the second examination, irrespective of whether performed first during the warm or cold season, which suggests the seasonal period is less important compared with adaptation to the measurement procedure, resulting in a better sleep.

The steeper increase of heart rate during bicycle exercise in the cold period may indicate an increase of sympathetic nervous system reactivity to stress. In contrast, no season-related changes of the blood pressure response to the other stress tests was found in our study. In fact, the finding of higher peak values during mental and handgrip tests appeared to simply reflect higher baseline levels. However, if we consider that the blood pressure response to cardiovascular reactivity tests is, at least in part, representative of daily challenges and that the damage due to hypertension is related not only to the average blood pressure but also to the blood pressure variability, then this observation could be consistent with the finding of higher cardiovascular mortality in the cold season.

In our study, a comparison was not made between extreme conditions for the variations of temperature between the cold and warm months. In fact, the difference of outdoor maximal temperature between the two periods averaged 12° C and, in several instances, less than 5° C. This close range of temperature probably caused an underestimation of the maximal seasonal effect on blood pressure, but it also allowed us to observe over a more continuous range the relation between temperature and blood pressure changes (Figure 2).

Finally, it should be noted that this study was performed in a group of subjects in the high normal to mild hypertensive range, and it is uncertain to what extent its results can be extended to the more severe forms of hypertension. However, the demonstration of an important seasonal effect on blood pressure in these patients may have important clinical implications. In fact, from a clinical point of view, the majority of patients who seek medical advice for arterial hypertension are in the upper normal to mild hypertensive range and represent a clinical problem in a decision to start pharmacological treatment. In these patients, especially if ambulatory blood pressure measurements are performed, the period of examination should probably be taken into account.

In a broader perspective from an epidemiological point of view, our finding can also have important implications. For example, if 90 mm Hg is taken as a fixed cutoff point for arterial hypertension and variations of environmental temperature of 20° are assumed to shift the diastolic blood pressure distribution in a given population by 5-10 mm Hg, then, according to the season during which the determinations are made, the differences in the estimated prevalence of arterial hypertension could be as high as 10-30%.

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of Pisa, which provided the data of maximum outdoor temperature.

References


KEY WORDS • blood pressure • environmental temperature • stress tests
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